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INFLUENCE OF GEOMAGNETIC FIELD ON EXTENSIVE AIR SHOWERS OF COSMIC RADIATION

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ABSTRACT. G. Cocconi (1954) pointed out that the deflection of air shower particles in the earth's magnetic field should produce some ellipticity of shower structure, and hence the lateral distribution of electrons around the shower axis should not be circular, but elliptical, with the major axis in the East-West direction. This effect was investigated at Gulmarg (alt. 2710 m 24°–36′ N-geomagnetic lat.,) with two G M. counter telescopes, for three separations 10 m, 25 m, and 40 m. The results show that there is a significant difference between the shower rates from East-West and North-South directions. This asymmetry in the shower rates is found to increase with the separation, and the zenith angle of the telescopes.

INTRODUCTION

G. Cocconi (1954) pointed out that D_m, the displacement of air shower particles due to the earth's magnetic field is not negligible in comparison with D_s, the projected lateral displacement due to multiple coulomb scattering, and this effect might be large enough to be detected as an asymmetry in the lateral distribution of electrons in air showers. It means the electrons are distributed elliptically, around the shower axis.

It has been evaluated in the first approximation, that the ratio of the two displacements is given by

$$D_m/D_s = 0.22 \cos \lambda/P$$

Where λ is geomagnetic latitude, and

P is air pressure in atmospheres.

The combined displacement is $D_{m+S} = \left[D_m{}^2 + D_S{}^2 \right]^{\frac{1}{2}}$: so that

$$D_{m+S} = D_S \left[1 + \left(\frac{0.22 \cos \lambda}{P} \right)^2 \right]^{\frac{1}{2}}$$

$$\simeq D_S \left[1 + \frac{0.024 \cos^2 \lambda}{P^2} \right]$$

P. Chaloupka (July, 1954) measured this effect on the top of "Lommicky' Stit" (alt. 2634 m : 48° N. geomagnetic latitude) with two G. M. counter telescopes. The separation of the telescopes was 7 m. The telescopes were inclined at 45° zenith angle and successively directed towards East, West, South, and North. Fourfold coincidences were taken. He reported nearly 20% more showers arriving from the E-W direction than from N-S direction. Due to large statistical errors he did not draw any conclusion. Later Dubinsky, Chaloupka, *et al.* (1956) continued the investigation (alt. 1778 m: 48°N. geomagnetic lat.) in which they fixed up the position of the shower core, and measured the particle densities to the West and South of the core, at three distances 15.5 m, 30 m, and 50 m. Though they did not find any variation for 15.5 m, they observed 40% and 60% greater densities in the West direction than in the South for 30 m, and 50 m distances respectively. Even in this case the statistical errors were large. The present investigation was carried out at Gulmarg (alt. 2710 m : 24°-36′ N. geomagnetic lat.) with improved statistics.

EXPERIMENTAL

The experimental arrangement was similar to that of Chaloupka, and the block diagram is shown in Fig. 1. It consisted of two G M. counter telescopes T_1, T_2, with two trays in each. In each tray there were four counters (size 52 × 584 mm) filled with Argon and petroleum-ether. The separation of the counter trays in the telescopes was 950 mm. The pulses from the trays were carried to the cathode-follower and from there to the coincidence circuit, through a low impedance coaxial cable, type *KD*-49. Only fourfold coincidences were recorded by the recording unit. The counter trays were mounted on an aluminium frame, which was fixed to a wooden stand in such a way that the telescope can be fixed at any particular zenith angle.

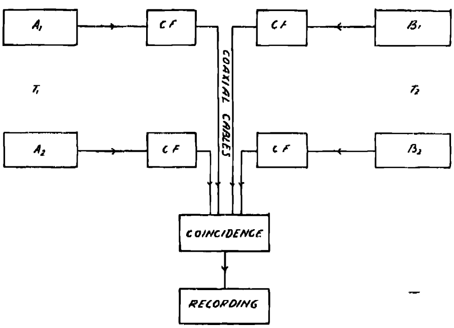

Fig. 1.

The asymmetry in the rate of showers was measured for three distances 10 m, 25 m, and 40 m between the telescopes. The telescopes were directed towards East, West, South, and North at zenith angles 0°, 15°, 30°, 45°, and 60°

and fourfold coincidences were recorded. Counters with a minimum plateau of 200 V were used in the experiment, and they were tested every day before starting the apparatus.

RESULTS AND DISCUSSION

The results of the experiment are given in Tables I, II, and III, for the three separations 10 m, 25 m, and 40 m. In any direction if the total number of counts recorded is M, during the total time T hours, then the shower rate in that direction is M/T per hour. The error in the shower rate is taken as $M^{\frac{1}{2}}/T$

The first table represents the shower rates from East, West, South, and North directions with the corresponding errors. In Table II the average shower rate from East-West directions is taken as x and the average shower rate from North-South directions as y. Next, the ratio x/y is calculated for the three separations and all the zenith angles as shown. If the circular symmetry of electrons around the shower axis is to be correct, the ratio x/y should be unity. But it can be seen that in all the cases, without exception, the ratio is larger than unity and far beyond the statistical errors. This clearly indicates that electrons in extensive air

TABLE I

Counting rates of showers from East, West, South, and North directions with corresponding errors

	Zenith angle Z	Showers per hour from the East $N_e \pm \Sigma_e$	Showers per hour from the West $N_\omega \pm \Sigma_\omega$	Showers per hour from the South $N_s \pm \Sigma_s$	Showers per hour from the North $N_n \pm \Sigma_n$
	0°	94.4±2.5	———	87.0±2.3	———
	15°	79.4±1.9	81.5±1.9	72.1±1.7	72.1±1.7
10 m	30°	69.5±1.5	75.0±1.9	63.0±1.5	61.2±1.5
	45°	60.4±1.5	66.1±1.7	52.9±1.3	53.8±1.3
	60°	50.9±1.3	58.0±1.5	45.6±1.2	47.4±1.2
	0°	58.9±1.9	———	52.5±1.6	———
	15°	49.5±1.5	54.9±1.7	40.0±1.3	40.6±1.2
25 m	30°	45.0±1.0	48.2±1.5	33.2±1.0	33.3±1.0
	45°	40.2±1.2	45.2±1.5	28.2±0.9	28.7±0.9
	60°	35.0±1.0	37.1±1.2	22.4±0.7	23.3±0.7
	0°	38.4±1.5	———	30.0±1.2	———
	15°	32.6±1.2	35.3±1.3	24.7±1.0	24.9±1.0
40 m	30°	29.7±1.2	32.6±1.3	20.6±0.9	20.2±0.7
	45°	26.5±1.0	29.5±1.2	16.5±0.6	16.5±0.6
	60°	24.5±0.9	25.9±1.0	13.3±0.6	13.3±0.6

TABLE II

Ellipticity and percentage asymmetry of extensive air showers

	Zenith angle Z	Average shower rate from E–W $x \pm \Sigma_x$	Average shower rate from N–S $y \pm \Sigma_y$	Ellipticity $\frac{x \pm \Sigma_x}{y \pm \Sigma_y}$	Percentage asymmetry $F = \frac{2(x-y)}{(x+y)} \times 100\%$
10 m	0°	94.4±1.8	87.0±1.6	1.09±.029	8.2±2.6
	15°	80.5±1.4	72.1±1.2	1.12±.027	11.0±2.4
	30°	72.3±1.2	62.1±1.1	1.16±.028	15.2±2.4
	45°	63.3±1.1	53.4±0.9	1.19±.029	17.0±2.4
	60°	54.5±1.0	46.5±0.9	1.17±.031	15.8±2.7
25 m	0°	58.9±1.4	52.5±1.1	1.12±.036	11.5±3.2
	15°	52.2±1.1	40.3±0.9	1.30±.040	25.7±3.0
	30°	46.6±0.9	33.3±0.7	1.40±.040	33.3±2.8
	45°	42.7±1.0	28.5±0.7	1.50±.051	39.9±3.3
	60°	36.1±0.8	22.9±0.5	1.58±.049	44.7±3.0
40 m	0°	38.4±1.1	30.0±0.9	1.28±.053	24.6±4.1
	15°	34.0±0.9	24.8±0.7	1.37±.053	31.3±3.8
	30°	31.2±0.9	20.4±0.6	1.53±.063	41.9±3.9
	45°	28.0±0.8	16.5±0.4	1.70±.064	51.7±3.5
	60°	25.2±0.7	13.3±0.4	1.89±.078	61.8±3.7

TABLE III

East-West percentage asymmetry of extensive air showers

Zenith angle Z	East-West asymmetry of extensive air showers		
	10 m	25 m	40 m
0°			
15°	2.61±3.34	10.34±4.32	7.95±5.38
30°	7.61±3.32	6.86±3.82	9.30±5.70
45°	9.01±3.57	11.70±4.45	10.71±5.53
60°	13.03±5.87	5.82±4.31	5.55±5.32

showers are distributed elliptically around the shower axis. The percentage asymmetry between the shower rates from E-W and N-S directions is given in the last column of Table II.

The errors in the ellipticity and the percentage asymmetries are calculated as follows :-

If (F) is a function of both x and y then the error in F is given by

$$\Sigma^2 = \left[\frac{d(F)}{dx}\right]^2 \Sigma_x^2 + \left[\frac{d(F)}{dy}\right]^2 \Sigma_y^2$$

where Σ_x and Σ_y are errors in (x) and (y), and Σ is the error in the function (F).

Then a graph is drawn with the zenith angles along the abscissa and the percentage asymmetries along the ordinate for the three separations of the telescopes. From the graph it is clear that there is a systematic increase in the asymmetry with zenith angle. It can also be seen that at any particular zenith angle the asymmetry increases with the separations of the telescopes. Of course the same arguments hold good for ellipticity also. The percentage asymmetry and elipticity will increase by about 4 or 5% if the counting rates of showers only from West and South are taken into consideration, because the average shower rate from *E-W* is less than the individual shower rate from West, though the shower rates from North or South are exactly the same.

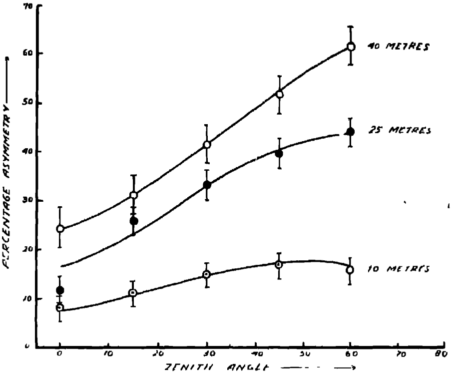

Fig. 2. Zenith angle versus percentage asymmetry.

Though the main aim of the investigation is to find out the geomagnetic effect on extensive air showers, there is one more interesting point At all zenith angles from 15°-60° for the three separations 10 m, 25 m, and 40 m, the shower rate is slightly more from West than from East direction This East-West asymmetry of extensive air showers is shown in Table III. In view of the very large statistical errors, and very poor angular resolution of the telescopes, it is felt better not to draw any definite conclusion. But it appears that there is some East-West asymmetry for extensive air showers also. From Table III it can be seen that for 10 m separation the asymmetry gradually increases from 15° to 60° zenith, whereas for 25 m, and 40 m, it reaches a maximum at 45° zenith and then comes down. To arrive at any conclusion regarding this East-West asymmetry of extensive air showers, more data are needed

CONCLUSION

At moderate latitudes and mountain altitudes the geomagnetic field has a considerable and well detectable influence on the density distribution of extensive air showers. The percentage asymmetry between the shower rates from E-W and N-S increases not only with the separation of the two telescopes but also with the zenith angle at which the telescopes are inclined. There appears to be 5 to 10% East-West asymmetry also for Extensive air showers.

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REFERENCES

Chaloupka, P., 1954, *Phys. Rev*, **96**, 1709.

Cocconi, G., 1954, *Phys Rev.*, **93**, 646; *Phys. Rev*, **94**, 796; *Phys Rev.*, **95**, 1705 (Errata)

Dubinsky, J. *et al*, 1956, *Czechosl. Journ. Phys*, **6**, 1, 29.

Galbraith, W, 1958, Extensive Air Showers; Butterworths Scientific Publications, 66.